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Ion Production Rates and Cross-sections from the Atmospheric Observations and Comparison with the Cloud Experiment Results

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Abstract. We present and discuss experimental results obtained from the measurements of cosmic ray fluxes and ion concentrations at different altitudes (from ground level up to 30-35 km) and latitudes (from equator to polar regions) in the Earth's atmosphere. We calculated ion-production cross-sections and ion production rates from these data sets. The same characteristics are possible to be derived from the CLOUD experimental data using ion concentrations, particle beam intensities, etc. We discuss the methods of estimation of these characteristics in the CLOUD experiment.

Keywords: cosmic rays, ionization, cross-section, ion production rate
PACS: 94.20.Qq, 94.30.Hn

INTRODUCTION

In this paper we present short description of the long-term cosmic ray measurements in the atmosphere provided by the Lebedev Physical Institute of the Russian Academy of Sciences. Also, we used experimental data on the light ion measurements in the atmosphere obtained by the Central Aerological Observatory of the Roscomhydromet of the Russia. From these data sets we calculated the ion-production cross-sections (σ) and ion production rates (q) at different altitudes and latitudes in the atmosphere.

The same values σ and q can be defined in the CLOUD experiment where ions are produced by the charged particle fluxes from the accelerator. Finally, we present the results of the comparison ion-production cross-sections and ion production rates obtained in both experiments.

COSMIC RAYS AND IONS MEASUREMENTS IN THE EARTH'S ATMOSPHERE

The galactic cosmic ray (GCR) fluxes are permanent and main natural source of ionizing charge particles in the Earth's atmosphere. The GCR mostly consist of protons (~85-90 % of total flux) and charged nuclei in wide energy range (the 10^6-10^{20} eV). When the GCRs propagate through the atmosphere they create secondaries, so called cascade charge particles in wide energy range. These secondary charge

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particles are measured regularly in the Earth's atmosphere since 1957 in the long-term cosmic ray experiment carried out by the Lebedev Physical Institute of the Russian Academy of Sciences (LPI RAS) at several locations [1, 2]. As an example, the GCR fluxes time variations at the maximum absorption curve (Pfotzer's maximum) at different latitudes in the Earth's atmosphere are shown in Figure 1.

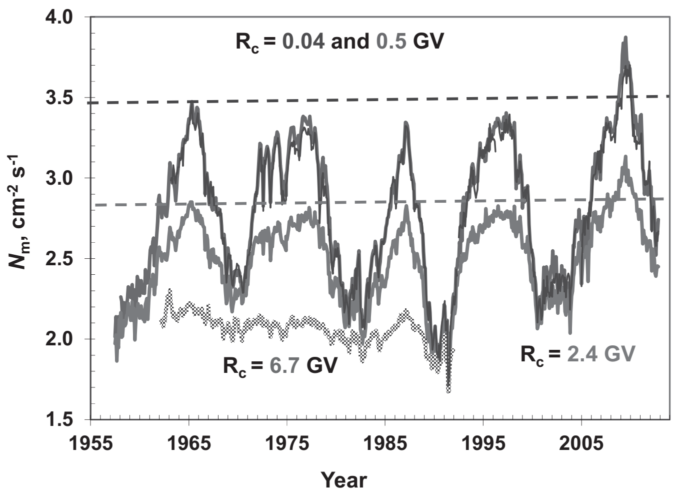

FIGURE 1. Monthly averages of cosmic ray fluxes in the maximum of absorption curve (Pfotzer's maximum) at different latitudes in the Earth's atmosphere. Curves correspond to the polar northern region (green curve; Murmansk region, geomagnetic cutoff rigidity Rc=0.5 GV), southern polar one (blue curve; Mirny station in Antarctica, Rc=0.04 GV), middle northern latitude (red curve; Moscow region, Rc=2.4 GV) and northern low latitude (light brown; Alma-Ata region, Rc=6.7 GV).

We note, that in this experiment the cosmic ray fluxes are recorded at ~ 50 different altitudes in the atmosphere from the ground level up to 30-35 km. Time variation profiles at these altitudes are almost the same, but their amplitudes are decreased when the atmospheric depth is increased.

Ionization of air and ion concentration measurements in the atmosphere were provided in the past in various experiments [3,4]. Figure 2 shows the altitude dependences of light ion concentrations and cosmic ray fluxes as a function of the atmospheric depth. These dependences were obtained at several latitudes with different geomagnetic cutoff rigidities Rc. We note similarity of the curves presented at left and right panels of the Figure 2.

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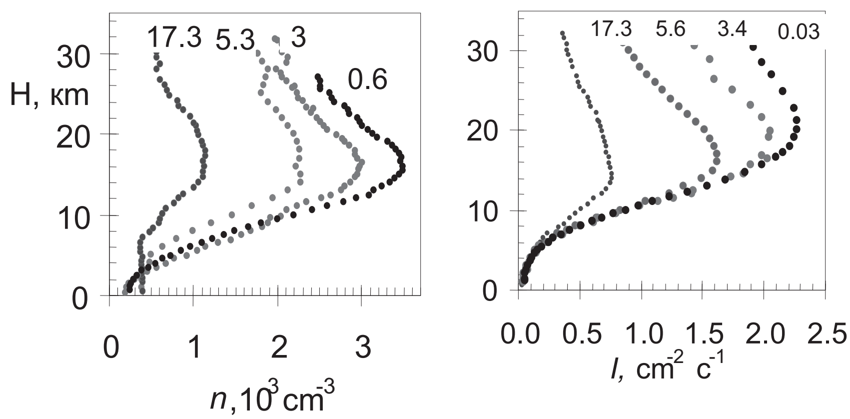

FIGURE 2. The altitude profiles of light ion concentrations (left) and cosmic ray fluxes (right). These dependences were obtained at several locations with different geomagnetic cutoff rigidities Rc (upper numbers in GV).

Monthly averages of cosmic ray fluxes in the maximum of absorption curve (Pfotzer's maximum) at different latitudes in the Earth's atmosphere. These curves correspond to the polar northern region (green curve; Murmansk region, geomagnetic cutoff rigidity Rc=0.5 GV), southern polar one (blue curve; Mirny station in Antarctica, Rc=0.04 GV), middle northern latitude (red curve; Moscow region, Rc=2.4 GV) and northern low latitude (light brown; Alma-Ata region, Rc=6.7 GV).

Comparative analysis of results of the CRs and ions measurements in the atmosphere allowed us to calculate the ion-production cross-sections and ion production rates at different altitudes.

CLOUD EXPERIMENT: CHARGE PARTICLE FLUXES AND IONS

In the CLOUD experiment charged particles (3.5GeV/c pions) from CERN accelerator PS215 penetrate into the CLOUD chamber (volume~ 26m^3) and generate ions inside the chamber [5]. The scintillation hodoscope provide measurements of the space and time distributions of charged particle flux. The experimental devices NAIS and APITOFF provide continuous records of the positive and negative ion concentrations in the CLOUD chamber. We used these data sets to calculate the ion-production cross-sections and ion production rates in the chamber under given conditions. We discuss method of the σ and q value calculation and compare results obtaine in the atmosphere and in the CLOUD experiment.

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